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SILVER BOW CREEK

PRELIMINARY REMEDIAL

TECHNOLOGY REVIEW

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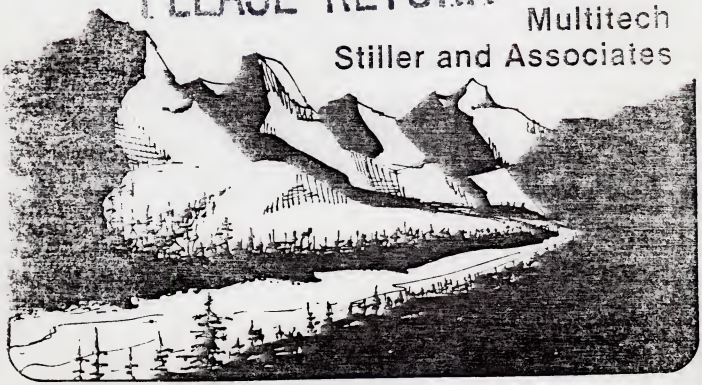

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SILVER BOW CREEK REMEDIAL INVESTIGATION

PRELIMINARY REMEDIAL TECHNOLOGY REVIEW

Submitted To:

Solid Waste Management Bureau
Montana Department of Health and Environmental Sciences
Room B-201
Cogswell Building
Helena, Montana 59620

Submitted By:

MultiTech
P.O. Box 4078
Butte, Montana 59702

And

Stiller and Associates
130 Neill Avenue
Helena, Montana 59601

April 13, 1984

MultiTech

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

This report was prepared by MultiTech and Stiller and Associates for the Solid Waste Management Bureau (SWMB) of the Montana Department of Health and Environmental Sciences (MDHES) under Contract No. 40325-1202503. This contract requires MultiTech and Stiller and Associates to provide Remedial Investigation Support to MDHES for the Silver Bow Creek "Superfund" Site. This Preliminary Remedial Technology Review Report is the first document required under the contract.

This Preliminary Remedial Technology Review has been prepared to meet the following objectives:

- Identification of potential non-controlled releases of hazardous substances into Silver Bow Creek, from the Warm Springs Ponds, and into the Upper Clark Fork River;

- Identification of potential remedial actions or technologies to alleviate contamination of Silver Bow Creek; and

- Identification of data necessary to evaluate potential remedial technologies and describe the extent and severity of contamination.

Research for the preparation of this report included reviewing published and unpublished reports and personal communications. No field work was performed.

Potential problem areas identified included:

- Tailings deposits contributing sediments and trace elements to Silver Bow Creek;
- Point sources contribution of dissolved trace metals to Silver Bow Creek;
- Ground water trace element contamination from known and unknown tailings, wastes, or bedrock;
- Surface and ground water contamination by PCP and oil;
- Contamination of the creek by elemental phosphorous;
- Land contaminated from using Silver Bow Creek and the Upper Clark Fork River for irrigation;
- Livestock and livestock product consumers may be exposed to elevated levels of some contaminants from the use of Silver Bow Creek and the Upper Clark Fork River for irrigation;
- Local ground water contamination from the Warm Springs Ponds;
- The physical structures of the Warm Springs Ponds may not be able to withstand high flow events;

- Waterfowl associated with Silver Bow Creek, Warm Springs Ponds, and the Upper Clark Fork River may be carrying elevated levels of trace elements in certain tissues and may be exposing human consumers to these elevated levels;
- The Warm Springs Pond system, a NPDES permitted facility, does not always meet its NPDES permit limintations for zinc during the winter;
- The life span of the ponds at current operating conditions is unknown; and
- The elevated levels of zinc entering the Clark Fork River from the Warm Springs Ponds may be affecting trout production;
- The Mill-Willow bypass contributes water contaminated with heavy metals to the Upper Clark Fork River.

Potential and currently operating response actions to alleviate some of these problems were identified. To aid in the discussion of the remedial technologies they were identified as either source control technologies (preventing contaminants from entering the system) or treatment technologies (removing contaminants once they are entrained).

Potential source control technologies identified included:

- Removal of all contributing sources (such as tailings) and disposal in a safe manner;
- Drainage and treatment of water prior to release;

- Surface sealing of diffuse sources;
- Channel stabilization;
- Segregation of diffuse sources from ground water system;
- Revegetation of diffuse sources;
- Further treatment of point sources;
- Pumping and treatment prior to release;
- Segregation, pumping, and treatment prior to release;
- Treatment trench system;
- Sediment traps and check dams; and
- Runoff diversions.

Treatment technologies for land areas contaminated with irrigation identified include:

- Deep tillage of contaminated land areas;
- Liming of land areas contaminated;
- Change in irrigation source water;
- Reduction in land use;
- Profile modification;
- Organic amendments;
- Application of new soil layer;
- Treatment of water prior to use for irrigation;
- Slurry walls and grouting to affect subirrigation; and
- Change livestock and irrigation management methods.

The Warm Springs Pond system is an MPDES permitted facility that reduces the levels of contaminants from Silver Bow Creek and the

Opportunity Ponds prior to release to the Upper Clark Fork River. However, problems identified with the ponds have led investigators to suggest corrective actions which include:

- Removal of pond structures and sediments and revegetate;
- Dewater the ponds and revegetate;
- Dewater the ponds and cover with a gravel mulch;
- Reconstruction of pond structures to withstand high flow events;
- Construction of an upstream reservoir to control flow;
- Remove sediments from ponds;
- Reserve flow from tributaries to dilute contamination;
- Reconstruct a new facility on the Warm Springs Ponds site; and
- Construct a new treatment facility upstream or downstream of the Warm Springs Ponds.

Data needed to evaluate alternative remedial technologies and the data needed to determine the extent and severity of contamination were identified and described. Data types include:

- Ground Water;
- Surface Water;
- Tailings and Solids;
- Point Source Waste Streams;
- Soil;

- Vegetation;
- Geotechnical;
- Aquatic Biological;
- Terrestrial Biological; and
- Geology.

This document will be used to guide the development of the Remedial Investigation Work Plan, a report to MDHES from MultiTech and Stiller and Associates under the Remedial Investigation Support contract, and to serve as a starting point for the Feasibility Studies that will be initiated following completion of the Remedial Investigation.

1.0 INTRODUCTION

1.0 INTRODUCTION

The Comprehensive Environmental Response Compensation, and Liability Act (CERCLA - P.L. 96-510) requires the U.S. Environmental Protection Agency (EPA) to identify, list, investigate, and cleanup non-controlled hazardous waste sites not regulated by the Resource Conservation Recovery Act (RCRA - P.L. 94-580) of 1976 or the Toxic Substances Control Act (TOSCA - P.L. 94-469). CERCLA allows the EPA to enter into cooperative agreements with the states to administer the "Superfund" program within a state. Montana has entered into such a Cooperative Agreement with the EPA for the Silver Bow Creek "Superfund" site. The state agency responsible for administering this program, the Montana Department of Health and Environmental Sciences (MDHES) selected MultiTech and Stiller and Associates to perform final planning Investigation Support in preparation for Remedial Investigation studies on the Silver Bow Creek Site.

1.1 PROGRAM OBJECTIVES

The objectives of the Investigation Support Program are:

- Identify potential remedial technologies for "cleaning up" the Silver Bow Creek site and the data necessary to evaluate these potential technologies.

- Develop a work plan to guide field studies that produce the data requisite for: 1) assessing the extent and severity of contamination in the Silver Bow Creek-Upper Clark Fork system; and 2) evaluating potential remedial actions.

- Develop a Quality Assurance Plan that will ensure the integrity of data collected during the field studies.

- Develop a Health and Safety Plan that protects remedial investigation workers, remedial action workers, and the general public.

- Develop a site map that can be used for showing proposed sampling sites and project locations.

This Preliminary Remedial Technology Review Report was prepared to complete the first objective listed above. This report was prepared specifically to:

- Identify potential non-controlled releases that provide the basis for Siver Bow Creek's listing as a "Superfund" site.

- Identify previously proposed, currently operating, and potential remedial technologies for improving the condition of Silver Bow Creek and the Upper Clark Fork River.

- Identify the data requisite to evaluate identified remedial technologies.

This report will be used for two major purposes. The potential technologies identified in this report will provide a starting point for feasibility studies to be performed following the Remedial Investigation. The data needs identified will guide the preparation of the work plans. Exhibits referenced in this report are oversize documents delivered separately.

1.2 OVERVIEW OF SITE PROBLEMS

Silver Bow Creek, from its headwaters on Rampart Mountain northeast of Butte, to its confluence with Warm Springs Creek at Warm Springs is impacted by numerous human and naturally occurring factors that degrade it from a high quality mountain stream to a creek unsafe for human use, practically devoid of aquatic life, and potentially unsafe for agricultural use.

The degradation of the creek is primarily due to past industrial and municipal waste discharge practices. These practices have deposited mill tailings and discharged process waters, municipal sewage, oil, Pentachlorophenol (PCP), and other deleterious material into the creek. Some of these practices produced short-term impacts that disappeared soon after the discharge ended, while others continue to affect water quality years after they were released to Silver Bow Creek.

Major issues or areas needing to be addressed are:

- Ground water, surface water, point source contamination, and diffuse source contamination.
- Irrigation and Agriculture.
- The Warm Springs Ponds.

Exhibit 1 is a site map showing major drainages, major geographic locations, and point sources.

1.2.1 Ground Water, Surface Water, Point Sources, and Diffuse Sources

This section is a discussion of the problem areas affecting the Silver Bow Creek drainage and a portion of the Upper Clark Fork River drainage (Exhibit 1). Impacts are addressed starting from the headwaters of Silver Bow Creek and proceeding downstream, with problem areas discussed relative to their general location along the drainage. The problem areas involve both point and diffuse source discharges and include a variety of contaminants.

The primary sources of contaminants to Silver Bow Creek are waste products from mining-related ventures that have been located in the drainage. These ventures include numerous mines, mills, and smelters at Butte and the Anaconda Mineral Company's (AMC) large Washoe Smelter in Anaconda, which together produced enormous quantities of

mine water, tailings, and smelter wastes. Early mining practices discharged wastes directly into Silver Bow Creek; plus tailings ponds were commonly built right in the channel itself, if built at all. These practices introduced massive volumes of material into the creek, which resulted in an extensive portion of the creek flowing on tailings instead of its natural stream bed. The primary remnants of these practices are the Colorado and Ramsay areas tailings, both of which are located in the modern floodplain zone.

AMC began treating its Butte Operations discharges in 1972 in order to meet MPDES permit requirements (Spindler 1976). These treatment steps which included recycling, ponds, and liming along with short-term measures aimed at minimizing the creek's contact with tailings, have helped improve the quality of Silver Bow Creek. Various municipal discharges over the years also added to the deterioration of Silver Bow Creek, but recent improvements at some locations have helped minimize these impacts.

1.2.1.1 Headwaters

Yankee Doodle Creek, a headwater stream of Silver Bow Creek is a high quality ephemeral stream prior to flowing into AMC's Yankee Doodle tailings pond. Yankee Doodle Creek feeds the Moulton Reservoirs, which are part of the Butte city water supply, above the Yankee Doodle tailings pond.

1.2.1.2 Anaconda Minerals Company Operations

Runoff from AMC lands permitted by Montana Department of State Lands (MDSL) under the Metal Mines Reclamation Act have drained into the Berkeley Pit since the cessation of operations in June 1983. Between 1972 and 1983 there were three MPDES permitted discharge points from Butte operations. These discharge points were the Barrel ponds near the Weed Concentrator, an emergency discharge from the Yankee Doodle ponds, and a discharge from the East Continental pit. All discharges eventually entered the Butte Metro Storm Drain.

No future discharges are expected from the operations unless the mine reopens or until the water level in the Berkeley Pit rises to where it becomes necessary to pump the pit in order to prevent overflow. It is anticipated that the pit water level will be kept below the bedrock-alluvium contact, which is approximately 300 feet below the south rim of the pit (5,300 feet AMSL). An ongoing ground water monitoring program being performed for AMC will also help determine a plan of action to minimize the impact on the local ground water (Grotbo 1984).

This potential problem is regulated by MDSL; and cooperation and exchange of data are encouraged to insure that any potential impacts to the CERCLA study area will be transmitted to the Solid Waste Management Bureau (SWMB) and project consultants. Any future discharges would continue to be regulated under AMC's MPDES permit and would be discharged to the Metro Storm Drainage.

1.2.1.3 Clear Water Ditch

One intermittent discharge, still exists in the vicinity of AMC's Butte operations, the Clear Water Ditch. The ditch borders the operations and diverts natural runoff from reaching disturbed mining sites. This ditch carries Elk Park Creek, Horse Canyon Creek, and any overland runoff from each of the operations to the Metro Storm Drainage. The discharge from the Clear Water Ditch is generally not a problem due to the undisturbed nature of the drainage area. However, during peak flows it can produce higher than normal metals and sulfate loads (Hydrometrics 1983e).

1.2.1.4 Metro Storm Drain

The Metro Storm Drain is a reconstructed reach of the original Silver Bow Creek channel that runs from the Weed Concentrator to the confluence of Blacktail Creek with Silver Bow Creek. The Metro Storm Drain has been a major contributor to metal and sulfate loading in upper Silver Bow Creek due to past AMC and ongoing storm sewer discharges (Casne et al. 1975).

Storm drain discharges were studied by AMC in 1979 and were found to contribute the majority of the iron, copper, and zinc entering Silver Bow Creek in Butte (Colvin 1979). The primary source of the contaminants was identified as runoff from inactive mines in the Butte-Walkerville area. An ongoing study by the MSDL Abandoned Mines Reclamation Bureau is evaluating possible contaminant sources

in greater detail. The storm drains carry runoff from all of uptown Butte west of the Berkeley Pit, including the numerous mine, mill, and smelter sites that are spread over the "hill".

There are also several potentially significant seeps along the banks of the Metro Storm Drain between Texas Avenue and Kaw Avenue bridges, but their impacts have not been well documented.

1.2.1.5 Blacktail Creek

Blacktail Creek has generally good water quality despite high fecal coliform levels and elevated metals concentrations in two of its tributaries, Basin Creek and Grove Creek, (Exhibit 1). The metals in Grove Creek are the result of the Clark Tailings which are located in the stream channel. Old diversion structures and recent efforts by the U.S. Soil Conservation Service (SCS) and AMC have helped minimize impacts from the site. The lack of long-term effectiveness of the existing control measures and loads resulting from high runoff events may pose potential problems (Hydrometrics 1983c). There are elevated metals loads in Grove Creek below the tailings and in the local ground water system. There are elevated nitrates in some of the monitoring wells between an adjacent landfill and the tailings, but it is not considered a problem (Leiter 1984).

The past high fecal coliform count in Basin Creek was probably the result of improperly constructed septic systems at residences in

the drainage (Casne et al. 1975). The fecal coliform count in Blacktail Creek has been above the level required for safe drinking water. Metal loads in Blacktail Creek are not a problem due to the low flow and moderate loads in Grove Creek.

1.2.1.6 Silver Bow Creek - Butte Area

The quality of Silver Bow Creek decreases significantly from Blacktail Creek to the Colorado tailings. The primary causes of this increase in contaminant loads are probably a result of discharging contaminated ground water (Hydrometrics 1983d) and metals in the Metro Sewage Treatment Plant effluent (James 1980). The poor quality ground water probably originates in tailings that have been covered by housing development or possibly from ground water percolation through highly mineralized geologic zones. Sampling during construction of the Metro Sewage Treatment Plant found the water from the excavation to contain high metals concentrations (Peckham 1979). The increase in metals loads in Silver Bow Creek in this segment suggests local ground water contamination. The contribution of the Metro Sewage Treatment Plant to metal and sulfate loading to Silver Bow Creek is reflected in two conflicting sets of data. James (1980) interpreted a series of grab samples from 1977-1978 and determined the Metro Sewage Treatment Plant to be a major contributor of zinc loads to Silver Bow Creek. Recent analysis of Metro Sewer Treatment Plant self-monitoring data from samples collected with a 24 hour continuous sampler, found insignificant zinc loads (Hydrometrics 1983d). While the 24-hour sampler probably

produced more accurate samples and flow measurements, the Metro Sewage Treatment Plant, due to its large discharge volume, is probably a significant contributor of pollutants such as nitrates and metals to Silver Bow Creek.

The sludge produced by the Metro Sewage Treatment Plant is disposed of on a 76 acre site near Ramsay (Figure 1-1). It is injected into the soil at a rate of 10-12 tons/acre and is operated as a disposal site. Monitoring has shown there has been no apparent detrimental effects on surface or ground water resources at this time (Leiter 1984).

1.2.1.7 Montana Pole and Treating Plant

The Montana Pole and Treating Plant southeast of the Colorado Tailings apparently discharged oils and PCP into Silver Bow Creek by means of a drainage ditch from about the time the plant opened in 1946 until about 1970. Recent investigations by the Water Quality Bureau (WQB) and SWMB into site discharges have led to the discovery of a large surface area affected by spills and a potentially large ground water area contaminated with oil and PCP. An existing seep from the bank of Silver Bow Creek is a known source of PCP in the creek. Studies to further determine the extent and specific source of the problem have been delayed.

In addition to Montana Pole and Treating Plant, two other operations are being investigated as sources of oils in the ground water in

the same vicinity. They are Lavelle Powder's shop, where used engine oil has reportedly been dumped on the ground for some time, and Montana Power Company's (MPC) shop where similar dumping has reportedly occurred. The Lavelle Powder site was formerly the Russel refinery where spills and discharges are thought to have occurred (WQB files). Little is known about the extent or nature of the dumping of oils on the two sites and their possible connection with the oil contamination of Silver Bow Creek, but WQB officials feel there is sufficient evidence to warrant further investigation. Even less is known about the effects of the historic oil and PCP discharges on downstream concentrations in sediments, because little if any sampling has been completed, except for the seep itself and the stream.

1.2.1.8 Colorado Tailings

The Colorado tailings (Exhibit 1) were commonly thought of as the major source of metals and sulfate loading to Silver Bow Creek. However, recent investigations raise some questions about the actual level of their impact.

Approximately 250,000 cubic yards of tailings are located in the original channel of Silver Bow Creek which was diverted during initial emplacement of the tailings. Riprapping the present channel has apparently been effective in minimizing the sediment loading of Silver Bow Creek.

Peckham (1979) found that metals loads in Silver Bow Creek from the Colorado tailings were small, and Hydrometrics (1983d) states that water quality samples from above and below the tailings indicate only a 2 to 7 percent increase in metals loads.

1.2.1.9 Ramsay Area Tailings

Below the Colorado tailings other tailings deposits are located in the floodplain of Silver Bow Creek in the vicinity of Ramsay, near the town of Silver Bow, and spread throughout most of the stretch from Butte to the Warm Springs Ponds (Figure 1-1). There are an estimated 1.5 million cubic yards of tailings along the reach of stream from Silver Bow to Miles Crossing alone. This area of tailings is possibly the major source of total and dissolved metals loading in Silver Bow Creek due to bank erosion, surface erosion and runoff, and ground water discharge. Silver Bow Creek is a losing stream near the community of Silver Bow (Exhibit 1) but is a gaining stream near Miles Crossing due to a narrow bedrock canyon. The tailings at Silver Bow are typically above the water table, while the tailings at Ramsay contain a shallow water table and exhibit surface salt deposits. Ground water samples from the Ramsay area show significantly worse water quality than those from the Colorado tailings (Hydrometrics 1983d). Erosion of tailings by Silver Bow Creek near Ramsay also occurs due to their location in the floodplain and lack of riprap or other channel stabilization structures.

Less extensive tailings deposits are present along Silver Bow Creek below Miles Crossing where thinner, more widespread deposits were produced by flooding and ice jams. There is no apparent increase in metals loads in this area and hence, the impact of these tailings deposits on Silver Bow Creek is probably minimal.

1.2.1.10 Rocker Septic Systems

The town of Rocker has a communal septic system that has been targeted as a high priority for replacement with a more adequate sewage treatment facility. Waste water effluent from a package treatment plant at the local truck stop is also discharged to Silver Bow Creek (Casne 1984).

1.2.1.11 Stauffer Chemical Plant

Stauffer's phosphate plant is somewhat of an unknown entity in the evaluation of potential problem areas affecting Silver Bow Creek. In the past, effluent was discharged into a local storm drain, but there has been a contained process since 1972, except for cooling waters which were not recycled until 1975 (Pasichnyk 1984). Little is known about the plant's tailings pond, except that it covers between 35 and 75 acres and is thought to be clay lined. There also appears to be a seepage ditch below it, but it is unknown if it ever contains water (Air Quality Bureau files).

Airborne emissions from the plant have been the cause of concern and significant monitoring and regulation by the Air Quality Bureau and may be the source of elevated fluoride levels in some local downwind stock ponds. There is no documentation of any ground water or surface water contamination due to the plant emissions. There was an incident of elemental phosphorous being found in Silver Bow Creek when a local boy was seriously burned in 1979. While Stauffer accepted responsibility as the source of the phosphorous, it was never determined how the phosphorous was introduced to the creek (Lloyd 1984). The potential for contamination of Silver Bow Creek by phosphorous remains unknown and requires investigation.

1.2.1.12 Opportunity

Opportunity is an unincorporated town (Figure 1-1) built over a system of drain tiles originally intended to lower the high local ground water table. The system has also been used by local residents to drain septic effluent. Accordingly it discharges high fecal coliform concentrations into Willow Creek.

Opportunity was targeted in the 1970's as a high priority site for development of a sewage treatment plant, but the townspeople voted it down. No action is currently underway to correct the situation. However the City of Anaconda has reserved space in its sewage treatment system to accommodate wastes generated by Opportunity.

1.2.2 Irrigation and Agriculture

Irrigated lands adjacent to either Silver Bow Creek or the Upper Clark Fork River have probably been contaminated by the use of irrigation water high in heavy metals and low in pH. Flood irrigation by tailings-laden surface water reduced productivity of irr - igated land in the past (Haywood 1910). It is estimated that currently several thousand acres of irrigated lands in Silver Bow, Powell, and Deer Lodge counties may have had crop and forage yields reduced or eliminated because of contamination from Silver Bow Creek and the Upper Clark Fork River (Strenfort 1984).

Seasonal flooding and formation of ice jams during winter and early spring have caused large acreages of land to be covered with water containing tailings materials which have been eroded from the headwaters of Silver Bow Creek, (Hydrometrics 1983g). A thin layer of tailings can be seen in many soils adjacent to the creek. Past use of surface water for flood irrigation has introduced tailings onto many irrigated fields. Not only has the sediment in Silver Bow Creek and the Clark Fork contaminated area soils but sediment has also clogged irrigation ditches as well as the channel system.

The sediments carried by Silver Bow Creek are often derived from tailings deposits which are typically low in pH and contain iron disulfide (pyrite). Oxidation of pyrite leads to a further decline in pH of the contaminated soils. The sediment also contains "heavy metals" such as zinc, copper, iron, manganese, cadmium, and arsenic.

The plant-availability of most of these elements increases greatly with the decline in pH caused by pyrite oxidation.

Contamination of irrigated soils is further complicated by poor quality ground water that is found in many of the irrigated areas. Irrigation along with river flood plains is often accompanied by a high water table resulting in a subirrigated condition of many crops (Konizeski et al. 1961, 1962). The contaminated ground water can flow upward into irrigated soils by capillary rise thus adding to the "heavy metal" load. Additionally, stack emissions from the smelting in the Anaconda/Butte areas has also added a surficial veneer of arsenic, copper, cadmium, lead, and zinc from smelter outfall, (MultiTech 1984).

Trace metal accumulation in feed crops and forages on irrigated lands has historically been a serious threat for livestock production in the Upper Clark Fork region, (Haywood 1910). Contamination of livestock water and forage due to an accumulation of heavy metals in the food chain may still be a problem, (Strenfort 1984, personal communication). A primary mechanism by which livestock metal accumulation can reach toxic proportions is through direct soil ingestion, (Thornton and Abrahams 1981). As many area soils have elevated levels of metals in the top few centimeters of the soil profile, soil ingestion is a serious concern.

1.2.3 The Warm Springs Ponds

The Warm Springs Ponds system is a MPDES permitted facility located near Warm Springs, Montana, used to treat mine-mill wastes from the AMC's Butte-Anaconda operations. The total pond area of 2,775 acres is operated by AMC under Department of State Lands permit No. 00030, (Hydrometrics 1983f).

The ponds were numbered 1, 2, and 3 in order of their construction. Pond 2 was constructed upstream from Pond 1 and and Pond 3 was constructed upstream from Pond 2. Pond 1 was used primarily to treat mill tailings and has been abandoned and dewatered. Some seepage water collects in Pond 1 and is pumped back into Pond 2. AMC has done some rehabilitation test work in Pond 1.

Ponds 2 and 3 make up the active pond area of 1,130 acres (Hydrometrics 1983f). Pond 2 has an average water depth of less than two feet, while the water depth in Pond 3 varies from approximately three feet near its inlet to twelve feet near its discharge (James and Searle 1981). The solids in Pond 2 and Pond 3 are a mixture of mill tailings and precipitation metal hydroxides.

The ponds are presently used to remove metals and sediments from Silver Bow Creek and Opportunity Pond discharges before discharge into Mill and Willow Creeks which are bypassed around the ponds. No mine-mill wastes are now discharged into Silver Bow Creek so the metals and sediments present in the stream are those removed from

old tailings deposited along the steambed, and from the Opportunity Pond discharge.

Current operation of the ponds consists of: 1) a liming operation above Pond 3 where lime is added at the inlet control structure by a timed auger; 2) two decant towers with control gates (to control the level of Pond 3) for release of water to Pond 2; and 3) a pump and lime treatment for seepage water below Pond 2 back into Pond 2; and 4) a control structure on Pond 2 to release the MPDES permitted discharge which combines with the Mill-Willow Bypass to form the Clark Fork River. Most of the dissolved metal and sediment removal occurs in Pond 3, with Pond 2 acting as a polishing pond (Hydrometrics 1983f).

There are several potential problems currently associated with the Warm Springs Ponds. These problems are: 1) the ponds lose some of their metal removing capacity during the winter and allow elevated levels of zinc to enter the Upper Clark Fork River (Philips 1983); 2) during high flows, Silver Bow Creek is partially diverted around the ponds allowing non-treated water to enter the river (Philips 1883); 3) the ponds are currently influencing local ground water conditions - both in amount and constituents (Hydrometrics 1983f); 4) the life span of the ponds for water treatment at current operating conditions is unknown (Hydrometrics 1983f); and 5) the physical structures of the pond system (dikes, inlets, and outlets) may not be able to withstand potential high flow events (Hydrometrics 1983f).

2.0 POTENTIAL SOURCE CONTROL METHODS

2.0 POTENTIAL SOURCE CONTROL METHODS

Response actions can be conceptually separated into source control actions and treatment actions. Source control refers to those actions that can be taken to prevent or reduce the deposition of contaminants into Silver Bow Creek. Treatment refers to those actions that can be taken to remove or reduce the contaminants from the creek or affected land area once they have been entrained.

The following discussions of potential response actions have been organized to reflect these two approaches. Where appropriate existing response actions are discussed.

The primary emphasis of source control remedial technologies is to control the quality and quantity of wastes and/or surface or ground water flows in such a manner that water quality degradation does not occur.

An extensive review of available literature was conducted to ascertain source control methods appropriate to the Silver Bow Creek/ Clark Fork River study area. Much of the source control research and technology has been dedicated to surface mining, specifically abandoned and operating coal mines and domestic sewage treatment. Because of this, pollution source control techniques for hard rock mine areas are limited, generally site-specific, and typically unproven on a large scale. Pollution control methods described

herein reflect those which are potentially applicable to the Silver Bow Creek study area.

It is probable that no single method will adequately control pollutants from all sources in the study area. Rather, specific techniques may be appropriate at certain sites, while a combination of methods may be necessary for successful pollution abatement at other sites.

Previous control techniques implemented along the upper reaches of Silver Bow Creek have primarily been directed towards controlling point sources. AMC controlled the effluent discharged by the Weed Concentrator to Silver Bow Creek (Spindler 1976) to MPDES permit limits. With cessation of all AMC discharges to Silver Bow Creek in Butte, the concentrator's pollution control techniques became relatively unimportant. If, and when mining operations are renewed, or the Berkeley Pit requires pumping, these point source control techniques may become important again. Other pollution control measures implemented along Silver Bow Creek include channel stabilization construction in the vicinity of the Colorado Tailings, improvements in the Butte Metro Sewage treatment plant, implementation of a contained system at the Stauffer Chemical Company, the Opportunity Ponds and the Warm Springs Ponds (a treatment facility-not a source control facility).

2.1 NO ACTION ALTERNATIVE

One option relative to mine and mill tailings waste contamination of Silver Bow Creek and Clark Fork River is that of taking no remedial action at all. This is primarily because of concern that any implemented remedial action may not reduce metals concentrations to levels tolerable to aquatic life and the affects that remedial actions may produce on the creek system.

Peckham (1979) states that actions such as tailings removal may not eliminate metals pollution. The tailings removal process could cause serious problems with sediment loading and sudden release to the stream of large volumes of stored, shallow, highly-mineralized, low pH ground water. Other techniques (e.g., revegetation, surface seals) were not considered to be viable pollution control mechanisms.

If no action is taken to control pollution sources to Silver Bow Creek and the Upper Clark Fork River, the streams will continue to exist in a manner similar to that of the present. Erosion and sedimentation impacts will continue to occur on reaches of Silver Bow Creek proximal to the tailings deposits. The shallow ground water system contained in many areas of the tailings will continue to contribute deleterious water to Silver Bow Creek. James (1980) estimates that the time required to leach copper and zinc from the existing tailings deposits is between 300 and 400 years.

2.2 NON-POINT SOURCE CONTROL METHODS

2.2.1 Removal of Tailings

Removal of the mine and mill tailings and subsequent disposal in a chemically inert and hydrologically isolated area has been proposed by several investigators. Approximately 2.3 million cubic yards of tailings are distributed along Silver Bow Creek between Butte and Gregson (Peckham 1979). Removal of such an enormous volume of material would certainly prove costly, and the likelihood of success of eliminating metals pollution in Silver Bow Creek is unknown.

Tailings removal could be accomplished by several means. Typically, removal is completed utilizing backhoes, draglines, or other comparable equipment for the excavation of the material. It is then transported using trucks to a disposal site. Other suggested tailings removal mechanisms include slurrying the material through a pipeline or using various types of pneumatic or hydraulic systems.

Disadvantages associated with tailings removal include impacts associated with turbidity as a result of sediment disturbance, as well as the sudden release to Silver Bow Creek of large volumes of stored, shallow, highly-mineralized ground water. These circumstances would certainly have serious effects on the re-establishment of downstream aquatic life.

Special importance was also placed on locating an environmentally safe tailings disposal site. Disposal site alternatives that have been proposed include the Opportunity Ponds (James 1980), the Yankee Doodle Tailings Ponds, and the Berkeley Pit (MBMG 1983). Detailed analyses of these sites relative to waste disposal have not been completed.

2.2.2 Drains, Cutoff Walls, Slurry Walls

One of the primary contaminant sources to Silver Bow Creek is the shallow, highly-mineralized, ground water system contained in the mine and mill tailings adjacent to the stream (Hydrometrics 1983). Control of this pollutant source is of prime importance in implementing a plan to enhance the quality of water in Silver Bow Creek and Clark Fork River.

Three common types of control devices have been used successfully in containing contaminated ground water systems. All of these controls may have specific applicability to the Silver Bow Creek study area and problems. These include horizontal drains, cutoff walls, and slurry walls. Drains are typically constructed by placing either coarse gravel, tile, or perforated pipe in a trench, placing coarse material adjacent to the drain to enhance permeability, and backfilling with topsoil or clay. Such drains are installed to collect leachate, alter ground water gradients, or lower the water table for site dewatering. Collected leachate is then

either gravity-fed or pumped to a holding tank or pond where it is either treated or evaporated.

Cutoff walls are used as a buffer zone to either direct uncontaminated ground water away from an affected area or to direct contaminated ground water to a treatment or holding site. Cutoff walls are constructed by driving web sections or sheet piling permanently into the ground. The types and materials of sheet piling are determined by site conditions and the contaminant. Each section is interlocking at its edges and, when combined with fine- to medium-grained fill, provides a water tight seal (EPA 1983).

Slurry walls are fixed, subsurface barriers constructed by pumping slurry, usually a soil, cement, bentonite, and water mixture, into a trench and allowing the slurry to cure. Slurry walls are used to contain contaminated ground water, divert uncontaminated ground water away from a polluted point source, divert contaminated water to a specific area for treatment, and provide a hydrologic barrier for a ground water system. Successful implementation of a slurry wall is primarily dependent on the formation of a filter cake on the trench wall during construction and on the backfill used (D'Appolonia 1980).

2.2.3 Surface Water Control Technologies

Sedimentation impacts on Silver Bow Creek and Clark Fork River are probably most severe during high runoff events when the opportunity

for significant erosion of mine and mill tailings adjacent to the stream is greatest. Control of runoff events is therefore important to any possibility of the re-establishment of an aquatic community in the streams.

Several methods of controlling surface runoff have been devised and successfully used. These may be useful on Silver Bow Creek and include dikes, terraces, channels, and grading techniques. Dikes are compacted earthen ridges designed to divert or retain surface flow. They are typically used to control floodwater or to contain and direct runoff. The size of dikes necessary for a specific area is dependent on such things as soil characteristics, topography, storm and runoff characteristics, and wind patterns.

Terraces are embankments constructed across a slope and are typically located in or near the active channel. Terraces are used to intercept and divert flow away from a site and control erosion by reducing slope length (EPA 1983). Design of terraces usually involves consideration of such items as capacity, slope, length, roughness coefficient, soil erodibility, material type, and construction procedure (ASAE 1978).

Channels are excavated ditches that are typically wide and shallow with varying geometric cross-sections. Channels are used to intercept runoff, reduce slope length, or to dewater shallow ground water aquifers. They may or may not be stabilized with vegetation or riprap. When channels are used as a ground water dewatering

mechanism, they may be lined or filled with specific types of material so that collected fluid is treated or decontaminated by contact with such material. Channel design is based on design flow, topography, erosion potential, and state regulations (EPA 1976).

Grading or regrading is used to modify the natural or existing topography and runoff characteristics of a site and usually involves the use of standard construction equipment. Techniques used in grading include spreading, excavation, compaction, scarification, trucking, and contour furrowing (EPA 1983). By modifying runoff patterns on disturbed sites through grading, water quality has been improved at numerous sites throughout the West (EPA 1978).

2.2.4 Water Table Adjustment

Several methods of water table adjustment may be applicable to Silver Bow Creek. These include pumping and treatment trenches.

2.2.4.1 Pumping

Water table adjustment is used to control contaminated ground water migration. The most common method of water table adjustment is pumping from wells. Ground water pumping typically uses a series of wells to remove contaminated ground water for treatment and/or subsequent discharge. As a result of use of multiple pumping wells, overlapping cones of depression are formed, the extent of which is

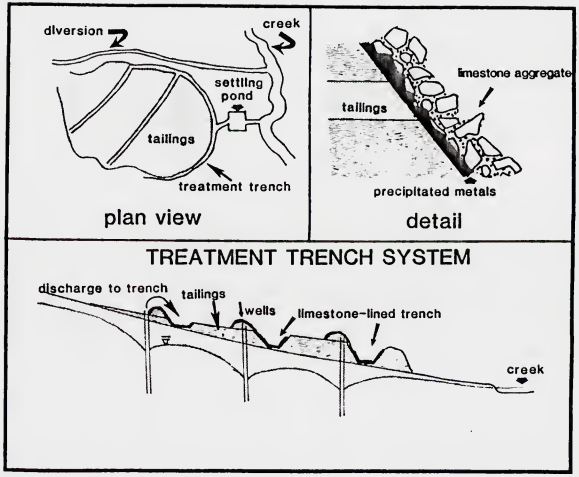
dependent on well spacing, pumping rates, and hydrogeologic and hydraulic characteristics of the pumped material.

Pumping can also be used in conjunction with other ground water controls (e.g., cutoff walls, slurry walls) to maximize their efficiency. The major disadvantages of pumping are the cost, maintenance, supervisory requirements associated with continuous operation of the system and treatment requirements prior to discharge. However, certain cases may necessitate the use of such methods (e.g., nearly flat hydraulic gradients).

2.2.4.2 Treatment Trench System

A sophisticated variation of the channel form of the Surface Water Control Technology (see Section 2.2.3) is called the "treatment trench system" and has specific application for tailings and thick overbank sediment deposits (Figure 2-1, Schafer 1984). The method simultaneously dewaters tailings and sediment deposits, treats and mitigates the acid nature of the effluent, and reduces wind erosion. The system could be used alone or in combination with cover-soiling and revegetation. Treatment trenches could also be used with a series of pumped wells to draw down shallow ground water beneath the tailings or sediment deposits. Well discharge can also be run through the trench before discharge.

The treatment trench system consists of a series of drainage ditches or channels (see Section 2.2.3) placed in the tailings or sediment



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TITLE: FIGURE 2-1.--TREATMENT TRENCH SYSTEM

so as to lower the water table. Trench sidewalls and bottoms are veneered with a layer of coarse limestone aggregate. The limestone bed neutralizes effluent collected by the drainage system. The design of the drainage system allows for addition of new gravels or replacement of spent gravels as heavy metal precipitates begin to clog the limestone bed.

When the crust thickness of the precipitates becomes too thick and impedes hydraulic conductivity, spent gravels should be removed and new gravels replaced. Gravels to be placed in the drainage system can be stock-piled on the upslope side of the trenches. These gravel berms slow wind velocity over the tailings surface, thus reducing wind erosion. Effluent from the drainage system can be collected in a central treatment facility if water quality is not adequate for discharge.

Geidel (1979) and others have shown that in sediments with a mixture of pyrite and neutralizing materials, the frequency of flushing by water influences the pH of underlying ground water. In sediments with ample carbonate and rapid water flux, the carbonate equilibrates quickly with water and readily neutralizes the produced acid. Pyrite oxidation is kinetically slower than carbonate equilibria but its solubility is far higher. As a result, sediments or tailings with infrequent water percolation episodes may develop water with a low pH despite an abundance of carbonates.

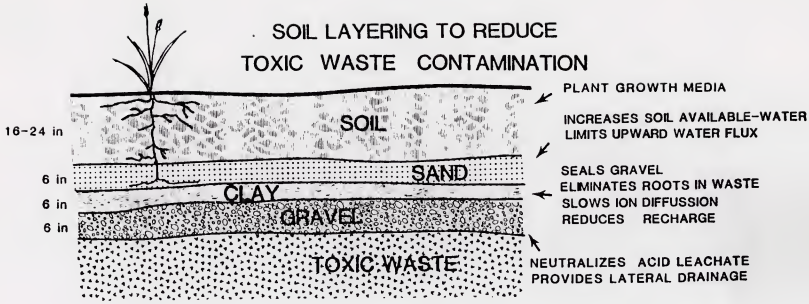
2.2.5 Surface Seals and Soil Covers

Sealing the surface of the tailings along Silver Bow Creek has been proposed as a remedial action alternative by Peckham (1979). The theory of utilizing a surface seal is to reduce infiltration and thus decrease leachate production in the ground water system. A cover soil is placed over the seal, and provisions are made for the establishment of a vegetative cover. Previous studies have had some success implementing such measures on experimental plots.

Surface seals typically consist of relatively impermeable material such as clay, synthetic liners, or other comparable materials that retard vertical migration of surface recharge. The seals extend laterally to provide adequate areal coverage of the affected site, and thus act to serve this source of ground water recharge. Cover soil would consist of types amenable to seed mixtures prescribed for specific areas.

Characteristics of tailings and of surrounding cover soil materials must be identified in order to develop suitable reclamation plans. An approach to cover-soil application termed "layering" (Schafer 1984) can provide a suitable root medium while reducing recharge of the tailings or upward flux of poor quality ground water (Figure 2-2).

The medium-textured, non-acid cover-soil provides an adequate root growth media. The sand layer reduces deep percolation of water and



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TITLE: FIGURE 2-2.--SOIL LAYERING SYSTEM

increases plant-availability water in the cover-soil (Hillel 1980). The clay would prevent loss of the sand into the gravel and further reduces percolation or root penetration into deleterious waste materials. The lime gravel would neutralize an elevated water table and provide a pathway for lateral seepage of excess water.

Liming of acid tailings materials may be a necessary aspect of project reclamation. It is often difficult to identify accurate lime rates for use on materials which contain pyrite. The SMP buffer test for lime requirement (Shoemaker et al. 1961) will underestimate total lime needs for pyrite-rich materials, but the acid-base balance approach (Sobek et al. 1978) will frequently over-estimate total lime requirement. Methods for lime incorporation are also significant because the effective root zone is likely to be limited by the practical depth of lime incorporation. Use of agricultural tillage equipment for incorporating lime materials would probably result in more adequate incorporation of lime than would the common practice of ripping by bulldozers.

Protective covers, such as gravel mulch, wood by-products, straw, geotextiles, and construction fabrics have been used to reduce wind and water erosion of tailings. Although these treatments are effective at reducing water and wind erosion, it has been found that leaching through surface amended tailings systems is not reduced. Therefore, their utility in reducing percolation and ajacent ground water quality degradation is questionable.

2.2.6 Channel Stabilization Alternative

Recommendations have been made to use channel stabilization techniques to lessen impacts to Silver Bow Creek from tailings deposits. Effective use of channel stabilization methods would curb the erosive processes acting on deposits adjacent to and in the stream. Sedimentation impacts to Silver Bow Creek would be reduced, and the quality of the streams would be enhanced.

Channel stabilization would consist of riprapping and regrading existing streambanks to expose underlying native soils and to allow revegetation (U.S. Forest Service 1979). The use of riprapped channels is common in the western United States to control erosion of streambanks, particularly where man's activities have altered natural systems. Riprap can consist of several types, including random, hand-laid, wire-enclosed rack, sacked concrete, and concrete-slab (Peil and Weaver 1975). The type of riprap necessary for any given site is dependent on several factors, including physical characteristics of the channel material, stream velocities, aesthetics, and cost. When random riprap is used, a filter blanket is recommended between the tailings and the riprap to control erosion of fine-grained materials underlying the riprap.

Although implementation of appropriate channel stabilization on Silver Bow Creek may decrease downstream sedimentation, the techniques will probably not significantly reduce metals loading to the stream by discharging ground water. Riprap is also aesthetically

displeasing to many persons and may not be an acceptable alternative for high visibility reaches of the stream. Finally, riprap other than the random type is very expensive and may not be cost-effective in all cases for the benefits it provides.

2.2.7 Revegetation

Revegetation is probably the most frequently recommended pollutant source control alternative for the Silver Bow Creek - Clark Fork River area. This alternative would stabilize tailings deposits both along the stream channels and their adjacent floodplains utilizing appropriate vegetation types. Vegetation is a natural deterrent to erosion and sedimentation and has been used successfully in numerous reclamation projects throughout the West.

Typically, revegetation is complemented with either soils/tailings amendments, or by the physical placement of uncontaminated cover soil on affected areas. Area-specific vegetative species are then introduced utilizing various methods ranging from natural invasion of vegetation to direct planting. Other revegetation approaches include direct seeding of tailings using metal and/or acid-tolerant plant species, fertilization, and mulching. Factors which may affect successful vegetation establishment include: depth of tailings, age of tailings, and depth of the underlying ground water table.

Revegetation of tailings adjacent to Silver Bow Creek using conventional revegetation techniques or with metal and/or acid-tolerant plant species may be difficult because of low pH ground water containing high concentrations of metals (Hydrometrics 1983e). This is due to upward movement of ground water by capillary action through the tailings into the plant root zone. Soil amendments such as liming may require frequent refurbishing because reacidification of treated soils commonly occurs in areas with shallow, low pH ground water systems.

2.3 POINT SOURCE CONTROL METHODS

2.3.1 Butte Metro Storm Drain

Surface runoff events carry loads of heavy metals and sediments to Silver Bow Creek via streets, gutters, and the stormdrains of Butte. As a result, the Metro Storm Drain system is a point source of Silver Bow Creek water quality degradation in addition to inactive mines and waste dumps in the Butte area. Several remedial alternatives are available.

2.3.1.1 Removal of Waste Dumps

This option would require locating a suitable disposal site. Previous authors have suggested using the Berkeley Pit or the Opportunity Ponds as disposal sites (James 1980; Hydrometrics 1983b). Additional disposal site study would be required, and transportation

also constitutes a significant concern. Revegetation of the sites would be necessary after removal of waste materials.

2.3.1.2 Revegetation of Waste Dumps

Before the dumps can be revegetated, it would be necessary to apply a soil cover or amend the material using lime, organic matter, and/or fertilizer (Hydrometrics 1983b). Slope modification may also be necessary in steep areas to provide geomorphic surfaces with minimized erosion potential.

Grassed waterways are also worthy of a consideration as a method of removing sediment during runoff occurrences. The waterways would have to be built and seeded with tolerant grasses which when established slow runoff velocities and allow sedimentation.

2.3.1.3 Sediment Traps and Check Dams

Sediment traps are commonly employed for erosion and sediment control. Frequently they are employed as temporary measures to reduce sedimentation until vegetation can be re-established. The more commonly used construction materials are strawbales and sandbags (EPA 1973). Structures are constructed in the drainageway where they decrease flow velocities and allow deposition.

Traps in the actual Metro Storm Drain channel probably should be more permanent than those near specific waste dumps. Building

materials such as stone or concrete should also be considered in the construction of check dams. Check dams require frequent maintenance and must be inspected after every storm event. Therefore, they should be located where they are easily observed and where there is adequate access for cleaning equipment. A suitable sediment disposal site must likewise be available.

2.3.1.4 Sedimentation Basins

Sedimentation basins usually require a much larger impoundment of water than check dams (sediment traps). Because of their larger size, they are built to withstand floods.

As with check dams, frequent maintenance is necessary. Ease of observation and accessability is required. Maintenance costs can be high because of the type and size of equipment likely to be employed.

2.3.1.5 Runoff Diversions

This is used to keep surface runoff from reaching its normal water course. Ditches, pipes, and flumes are commonly used. The object is to divert natural runoff around the problem areas such as waste dumps either temporarily or permanently. Diversions could also be used to catch runoff from the waste dump sites for treatment (such as a sedimentation basin).

If grassed waterways are used as diversions, it is unlikely that grasses could be established without soil additions or modification. Low pH and high metals concentrations could make plant establishment and/or growth impossible in some areas.

2.3.2 Butte Metro Sewage Treatment Plant

2.3.2.1 Inflow and Infiltration

Previous reports have indicated that infiltration of degraded ground water into the sewer lines is not a problem. Butte has a separate stormwater drain system; therefore, stormwater theoretically does not reach the sewage treatment plant. However, if future studies show that significant heavy metal concentrations originate at the sewage treatment plant, then it stands to reason that ground water or stormwater may be the cause. If significant infiltration is detected, sewer grouting or replacement must be considered.

The Metro Sewage Treatment Plant releases pollutants such as ammonia, chlorine, and organics into Silver Bow Creek under an MPDES operating permit. These pollutants must be considered during the remedial investigation as they will affect recovery of the stream during remedial actions.

2.3.2.2 Metal Recovery

Metal removal is commonly accomplished by neutralization and precipitation. Lime is frequently used to raise the pH. How high the pH must be raised to accomplish precipitation is dependent on the ion to be precipitated (EPA 1973). The process consists of neutralization by vigorous mixing with lime, then oxidation to oxidize ferrous iron to the ferric state. The oxidized metals are then settled out in a settling basin. It would require a significant amount of capital to modify the sewage treatment plant to accomplish metals removal. Sludge disposal would require locating a suitable site.

The heavy metal load contributed to Silver Bow Creek by the sewage treatment plant must be better defined before metals removal is seriously considered.

2.3.3 Montana Pole and Treatment Plant

As part of the problem evaluation, the boundaries of the affected area and the direction and rate of movement of the contaminants through the soil and ground water must be established. Preventive methods include sealing the work area and controlling surface runoff so that Pentachlorophenol (PCP) cannot migrate to the ground water or surface water. Additional remedial actions include constructing an impervious cutoff wall between Silver Bow Creek and the problem area; decontamination by removal of PCP and oil by

pumping from ground water wells; or from an interception ditch. If these approaches are used, a suitable treatment or disposal site will also be needed.

2.3.4 Town of Opportunity

The surest way to alleviate a fecal coliform problem is to eliminate the sources. This could be accomplished by installing sewers and pumping the sewage to the City of Anaconda's future sewage treatment system, or by implementing a local treatment system.

The present underdrain reaches the Clark Fork River without treatment. Conveying the discharge water to the Opportunity Pond system is also an option that should be investigated.

3.0 POTENTIAL CONTAMINATION TREATMENT METHODS

3.0 POTENTIAL CONTAMINATION TREATMENT METHODS

Potential contamination treatment methods includes methods for dealing with problems of soil contamination from using Silver Bow Creek or the Upper Clark Fork River as irrigation water and those methods used to remove contaminants from Silver Bow Creek and the Upper Clark Fork River down-stream of their deposition into the water.

3.1 IRRIGATION AND AGRICULTURE

Contamination treatment for irrigation water, soil, crops and livestock in the Upper Clark Fork area falls into three broad categories including soil treatment, water treatment, and management.

3.1.1 Soil Treatment

Past attempts at alleviating soil problems caused by irrigating with water from Silver Bow Creek included deep plowing, liming, and changing water sources.

A variety of mechanical treatments and soil amendments are available for mitigation of adverse soil conditions in irrigated soils in the region. These treatments used alone or in combination, though costly, can mitigate most of the problems associated with contamination from Silver Bow Creek.

For soils that have an accumulation of trace elements only in the top few centimeters, deep tillage with a moldboard plow (or other tillage which provides mixing) will dilute the surface accumulation of such elements throughout the top six to eight inches of soil. Heavy metal concentrations in the zone of germination (0-2 inches) will be reduced, thus allowing for stand establishment. Tillage used alone is only suitable for areas that have an average pH of six or greater in the top six inches of soil.

For soils that have a pH less than six and have an extreme accumulation of toxic elements, then liming is the best soil treatment. Appropriate lime rates for affected soils will likely range from one to ten tons per acre. Calculation of an appropriate lime requirement using standard soil tests is complicated by the presence of sulfides in tailings material. For soils without sulfides, the SMP buffer test (Shoemaker et al. 1961) is the best lime requirement test available (see Section 3.2.5).

Profile modification consists of tillage of the soil profile to a depth of two feet or more using a large single or tandem moldboard-type blade. Profile modification has been used with limited success in reclamation of dryland sodic soils in Alberta, and arsenic-contaminated orchard soils in Washington. Profile modification would bury toxic materials from the soil surface and place calcareous materials from the subsoil onto the surface.

Some soils have been identified along the Upper Clark Fork River that have both an accumulation of plant-available heavy metals and also a pH of 7.5 or greater. This suggests that liming of the soil will not affect the pH and thus perhaps will not reduce the heavy metal plant availability. For these soils it may not be possible to reduce heavy metal accumulation substantially. Use of heavy rates of organic amendments like manure will increase the soil cation exchange capacity and surface potential. As heavy metals interact strongly with surfaces and exchange sites in soil this may reduce the plant-availability of metals.

A final alternative, though perhaps prohibitively costly, would be to remove the layer of contaminated soils, or to apply cover soil to provide an adequate rooting zone for crops and forages. Problems with availability of cover soil materials, acquisition and spreading costs, plus the desirability of creating a new waste disposal site for contaminated soils (previously removed) will likely make this alternative treatment unfeasible.

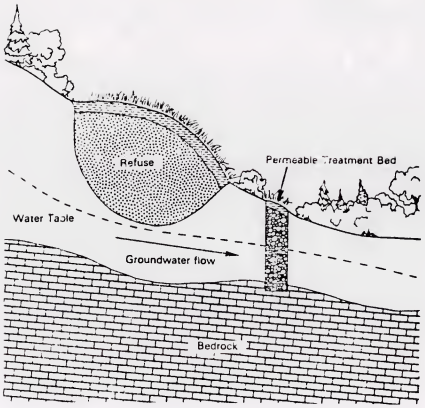
3.1.2 Water Treatment

If the flow of contaminated ground water into an irrigated area and accumulation of contaminants in the ground water by subirrigated crops is found to be a serious problem, then methods are available for treatment or reduction of ground water flow into irrigated areas. Permeable treatment beds have been used as a method for neutralizing contaminated ground water by raising the pH and lowering

the heavy metal content. The method consists of digging a trench to the depth of the base of the affected ground water zone and back-filling the trench with limestone gravel (Figure 3-1). The trench width is adjusted so that flowing ground water has time to react with the limestone. A problem with permeable treatment beds is their limited service life. As the ground water reacts with the limestone in the bed, iron oxide reaction products form which then coat the gravels; this coating reduces and eventually eliminates the reactive surfaces of the neutralizing limestone.

Another method that has been used to reduce the flow of contaminated ground water is to use either grout curtains or slurry walls to redirect ground water flow away from a particular area. Although all these treatments are costly, they are effective at redirecting shallow ground water flow (see Section 3.0). Another viable approach to the reduction of contamination from shallow ground water would be dewatering of the shallow aquifers by ground water pumping. For very shallow ground water systems a simple drainage network (Figure 3-2) designed to lower the water table to a depth of six or more feet below the soil surface could also significantly reduce the uptake of toxic trace elements from the shallow ground water system.

Treatment of the surface water being applied to irrigated areas would significantly decreased the future incidence of heavy metal contamination on irrigated soils. A discussion of water treatment can be found in Section 3.2 under Water Treatment Methods.



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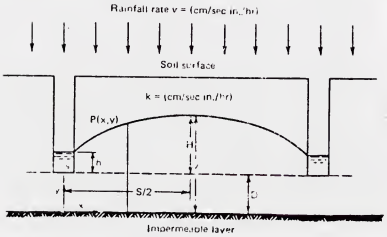
TITLE: FIGURE 3-1.--TYPICAL DETAIL OF PERMEABLE TREATMENT BED (Rogoshewski 1983)

DIAGRAM OF HOOGHOUDT'S DRAIN-SPACING FORMULA



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TITLE: FIGURE 3-2.--TYPICAL DETAIL OF A DRAINAGE NETWORK (Rogoshewski 1983)

3.1.3 Crop Irrigation and Livestock Management

A final approach to mitigating the contamination to irrigation water, soils, crops and livestock is to change management systems to alleviate toxic element accumulation throughout the food chain. A natural mechanism exists for reducing the accumulation of toxic elements in the food chain, which has often been called the soil/plant barrier (Parr et al. 1983). The soil/plant barrier concept includes three principles which tend to reduce food chain accumulation of toxic elements. These are: 1) trace element solubility in soils is limited; 2) many heavy metals tend to accumulate in non-edible portions of plants; and 3) plant phyto-toxicity often occurs before the elements accumulate to high enough levels to cause acute livestock mortality. As a result of the low pH and generally high solubility of the toxic elements in area soils, phytotoxicity is often the mechanism which tends to reduce metal accumulation in livestock forage. There are few notable exceptions to this concept of the soil/plant barrier to food chain accumulation. The elements arsenic, cadmium, selenium, and molybdenum tend to accumulate in forages without causing phytotoxicity and to reach levels that can be potentially toxic to livestock. Of these elements, high levels of cadmium (Munshower, 1972) are documented in the project area. Biologically toxic levels of arsenic, copper, cadmium, molybdenum, selenium, and zinc are currently suspected.

The process of soil ingestion by livestock will allow metals to bypass the plant uptake mechanism, thus allowing for rapid accumulation of metals in livestock (Egan and O'Cuill 1970). Healy and others (1974) found soil ingestion excessive in heavily stocked pastures during wet weather while Mayland and others (1977) found cattle grazing dryland crested wheatgrass to consume up to 20 percent by weight soil in their diet.

Different kinds of crops and varying species of forage have been found to have widely-varying tolerance to heavy metal accumulation. Many crops and forages either will not uptake heavy metals significantly and thus can survive on contaminates soils, or will take up such elements which then precipitate in the cell wall in the upper root crown. Use of these forage species would be one possible method to reduce toxic element transfer from contaminated soils to livestock. Only a few forage species show promise for growth under the more contaminated soils in the Upper Clark Fork River area. These forages have been developed in Great Britain and consist of cultivars of Agrostis tenuous that have been shown to have an extremely high tolerance for specific heavy metals. Individual cultivars normally only show tolerance for a single metal, (Wainwright and Woolhouse 1975). This system would only be applicable if the plant species are both tolerant and non-accumulators.

Changes in irrigation methods and systems can be used to alleviate past and future problems associated with soil contamination. It may be possible for example, to apply lime through the irrigation

system, thus reducing the application costs of lime. Lime injection into an irrigation system may also reduce the low pH and element loading of poor quality water being used.

A change in irrigation timing may allow irrigators to avoid use of water during spring runoff periods when sediment and dissolved trace element loading is greatest. Crop water requirements reach their peak in middle and later summer well after most flood events have occurred.

Irrigation systems could be modified to allow suspended sediments to settle out in sedimentation basins before being applied to fields either through sprinkler or gravity systems. Sedimentation traps would need frequent maintenance to remove sediment from the basins. In some gravity irrigation systems use of filter strips along the top of the field may be used to trap some sediment from the applied water before it reaches and spreads over the entire crop field.

A change in the source of water may be required to reduce the loading from heavy metals, sulfates, and sulfides onto previously contaminated soils. Adequate treatment of the upper reaches of Silver Bow Creek to reduce future sediment loading should eliminate the need to change the source of water.

Management of livestock grazing intensity, the species and age of animals exposed, and other measures to reduce heavy metal uptake and accumulation is the final area of management to be considered.

The amount of bare ground and thus the amount of soil ingestion is directly related to stocking intensity in grazing systems, therefore, reduction in stocking rate and grazing intensity could help reduce toxic element accumulation by livestock. Use of forage species that provide the maximum ground cover (rhizomatous grasses) will also tend to reduce soil ingestion.

Certain forage species termed "accumulators" have been found to develop extremely high concentrations of certain heavy metals without experiencing phytotoxic effects (Malaisse et al. 1978). These species, if utilized by livestock, could lead to trace element toxicosis. Forage tissue testing on individual species could be used to identify which, if any, forage species are "accumulators" of such elements, and then appropriate eradication techniques could be used to remove these species from the stand.

The method(s) applied for prevention or control of particular trace element toxicity (or subsequent deficiency in another element) in livestock varies by species, age of the animal, as well as normal feeding practices. Two alternative agronomic approaches not discussed above include the following:

- Decrease the rate of element absorption or increase the rate of excretion, possibly by use of metabolic antogonistics, thus inhibiting the toxic affects of elemental accumulation within body tissues or fluids, and

- Minimize access to potentially toxic plant materials by excluding particular livestock species from particular grazing lands or crop sources.

3.2 WATER TREATMENT

Several major alternatives are viable for consideration for water treatment. These are:

- Continue operation of the Warm Springs Ponds at current levels of management for the remaining life span of the ponds;

- Discontinue operation of the Warm Springs Ponds, reclaim the pond area, and construct a new treatment facility either upstream or downstream of the ponds;

- Continue operation of the Warm Springs Ponds with improved operational procedures and construct a new water treatment facility upstream of the ponds; and

- Reconstruct the Warm Springs Ponds to extend the life span of the ponds, improve metal removal efficiency, and establish a safety margin for high flow episodes.

3.2.1 Continue Operation of the Warm Springs Ponds

The Warm Springs Ponds are currently an operating treatment facility removing sediments and dissolved metals from Silver Bow Creek and the Opportunity Pond discharge. The Warm Springs Pond discharge is a MPDES permitted release. Operation of the ponds was described in Section 2.0.

Advantages

The Warm Springs Ponds provide treatment for Silver Bow Creek before it is discharged into the Clark Fork River (James and Peterson 1983). Silver Bow Creek picks up high concentrations of cations and anions from tailings deposited along its stream channel; these are removed to MPDES permit levels most of the time. During precipitation events high sediment loads are also washed from the tailings into the stream and are removed by the ponds. They also treat acidic seepages from the Opportunity Ponds (James and Searle 1981; James and Peterson 1983).

In their present condition the ponds are being used as a waterfowl nesting area and many types of waterfowl can be observed during the spring and summer.

Disadvantages

The ponds were constructed using alluvial material from the surrounding area. Most earth dams exhibit seepage and the Warm Springs Ponds area not exceptions. The ponds influence area ground and surface waters with seepage that is high in sulfates and trace elements, (James and Peterson 1983). As long as water remains in the ponds, ground and surface waters may be contaminated by seepage from the ponds.

The ponds are now almost full of solids. Continued use of the ponds to settle out suspended solids from Silver Bow Creek will eventually fill the ponds. The time required to fill the ponds cannot be specified precisely as the load on the ponds is changing. Pollution control efforts by the AMC have reduced the loading on the ponds, and the ponds may operate at their current effectiveness until Silver Bow Creek has a water quality high enough to bypass the ponds. However, not enough data currently exists to accurately predict the lifespan of the ponds.

3.2.2 Discontinue Operation of the Warm Springs Ponds, Reclaim the Pond Area, and Construct a New Treatment Facility

One alternative for alleviating some of the problems associated with the Warm Springs Ponds is to remove the ponds as a treatment facility and reclaim the area. Implicit in this option for the protection of the Upper Clark Fork River from contamination is the

need for a new treatment facility either upstream or downstream of the existing ponds. There are several considerations that would need to be addressed during an evaluation of this alternative. These considerations include:

- Reclamation technologies;
- Location and design of a new facility; and
- Impacts of a new facility.

Several reclamation technologies have been proposed for this area. These include: 1) drainage, removal of sediments, and revegetation; 2) drainage, treatment of sediments, and revegetation; and 3) drainage and treatment with a gravel mulch. The advantages and disadvantages of these reclamation techniques are summarized below and are discussed in detail in Hydrometric's (1983f) report on the Warm Springs Ponds.

3.2.2.1 Drainage, Removal of Sediments, and Revegetate

Advantages

This alternative would reduce or eliminate all the identified problems associated with the Warm Springs Ponds (assuming it is technically and economically feasible.)

Disadvantages

If the ponds are removed, the solids must be stored somewhere else. Transporting the solids from the ponds to a new location will be a major problem in itself. The hydroxide precipitates present in Ponds 2 and 3 become fluid and flow in the presence of water. This characteristic and the many streams and other sources of water in the area would make it difficult to transport the solids using normal methods.

If the ponds were removed down to the original contours, the newly-exposed materials may be as contaminated as the material removed. Years of contact with the solids in the ponds and the leachate from the solids may have affected the solids under the ponds.

If the ponds are removed, the treatment facility for Silver Bow Creek will be eliminated. Until the water quality in Silver Bow Creek improves, discharging it without treatment would degrade the upper Clark Fork River.

3.2.2.2 Dewater and Revegetate

Advantage

Dewatering the ponds will reduce the hydraulic head in the ponds and reduce seepage to the area ground and surface waters. The

seepage contains dissolved pollutants so decreasing seepage will reduce contamination of area ground and surface waters.

Revegetation would stabilize the pond sediments. Vegetation would prevent runoff during precipitation events from carrying sediments into the Clark Fork River system. Vegetation would also prevent wind erosion of sediments. If the pond area were dewatered and an appropriate diversion channel constructed, the potential for pond structure failure during a high runoff event would be reduced or eliminated.

Disadvantages

The sediments in the ponds may need treatment to support vegetation. The cost of revegetating 2,775 acres of land requiring treatment will be extremely high in terms of money and natural resources. Covering the ponds with a layer of limestone and then a layer of topsoil would require the destruction of the areas where the limestone and topsoil are obtained.

Much of the sediment in the ponds is precipitated metal hydroxides which do not have the structural stability of tailings. Dewatering and allowing the sediments to freeze may not be enough to insure the safety of the earth-moving equipment and operators necessary to prepare the ponds for revegetation.

Removal of the ponds from the system will eliminate the treatment of Silver Bow Creek. At current contaminant levels, the water quality of Silver Bow Creek is not good enough to insure the integrity of the Clark Fork River and its biological community.

3.2.2.3 Dewater and Cover with a Gravel Mulch

Advantages

This action would be basically the same as dewatering and revegetating but at a lower cost. It would not require the extensive effort required for revegetation.

Disadvantages

Many of the concerns expressed about dewatering and revegetation would apply here. Additionally, the gravel mulch would not be as aesthetically appealing.

3.2.2.4 Construction of a New Treatment Facility

If the ponds are drained and reclaimed then a new treatment facility will be necessary to remove contaminants from Silver Bow Creek, assuming that source control technologies will not be 100 percent effective in preventing contamination of the creek. Location of the new facility will be a critical factor which should be determined

by the location of contributing sources. The design and operation of a new facility should be determined by the contaminant load--both amount and constituency--found in the waters to be treated. Other factors that would determine the location for a new treatment facility include:

- Soil;
- Water table;
- Treatment technology;
- Land ownership;
- Liability;
- Topography;
- Biology;
- Environmental regulations;
- Public acceptance; and
- Operational responsibility.

The physical components and operation of a new facility would be determined by the location of a proposed facility, the contaminant load that needs to be removed, and the technologies available for contaminant removal. Some technologies available include:

- Liming and pH control for metals;
- Biological concentration for metals;
- Carbon absorption for organics;
- Aeration for organics and biological control;

- Sedimentation ponds; and
- Filtering for sediments.

These technologies are all proven and need only be scaled for expected loads. However, cost considerations will ultimately determine the most appropriate method or methods that could be applied to treatment of Silver Bow Creek water.

3.2.3 Continue Operation of the Warm Springs Ponds and Construct a New Treatment Facility Upstream of the Ponds

The only problem that this alternative really addresses is the possibility that the life span of the ponds for contaminant removal will be reached before source control activities reduce the contaminant load to acceptable levels. All the other disadvantages to continued operation of the ponds, discussed previously, would remain. Additionally, all the considerations presented above for a new facility would have to be addressed.

3.2.4 Reconstruct the Warm Springs Ponds

This alternative would address some but not all of the problems currently associated with the ponds. Problems that could be addressed in redesigning the ponds and changing operations include:

- The ability of the pond structures to withstand high flow events;

- The ability of the ponds to continue treatment of Silver Bow Creek water until source control activities have reduced contaminant loads to acceptable levels; and

- The ability of the ponds to effectively remove contaminants during the winter and high flow events.

Problems that could not be addressed--at least not very effectively--by reconstructing the ponds and changing their operation include:

- Ground water infiltration and contamination from the ponds;
- Potential waterfowl contamination;
- Organic contaminant removal (unless specific organic removal techniques were superimposed on "heavy metal" removal techniques); and
- The ability of the ponds to remove sulfates.

Some of the suggestions for improving the ponds include:

- Deepen and enlarge the ponds (Phillips 1983);
- Dike modifications to alleviate the potential for high flow failures (Hydrometrics 1983f); and
- Changing the liming operation to automatically respond to changes in pH and flow.

3.2.5 Other Proposed Treatment Actions

Phillips (1983) proposed several actions that could be used to alleviate some of the identified problems of the Warm Springs Ponds. These are produced verbatim below:

1) "Parts of the problem in Silverbow Creek stems from high flows. Encouragement of some form of water development, such as a reservoir, upstream of Butte on Blacktail Creek would provide a mechanism of regulating flows in a way that could minimize metals leaching, e.g., flows could be dampened thereby decreasing exposure of tailings piles during normal high flow periods. An upstream reservoir would also decrease turbidity and increase the effective lifetime of the Warm Springs Ponds.

2) "Reserve the flow of "clean" water (that will act to dilute copper) from tributaries that enter the Clark Fork downstream of the Warm Springs Ponds. An opportunity presently exists to do this in Warm Springs Creek because of the substantial amount of water that was previously withdrawn for the Anaconda Smelter. Perhaps part of the "Superfund" agreement with Anaconda would require transfer of their water rights from Meyers Dam to the mouth. This would prevent downstream irrigators from removing it before it reaches the Clark Fork. Part of the settlement might also involve purchase of additional water rights for downstream tributaries.

3) "Riprap and stabilize some key sections of Silverbow Creek that are particularly troublesome source of tailings."

4.0 DATA NEEDS

4.0 DATA NEEDS

The Silver Bow Creek Remedial Investigation has two major goals:

- Development of data to accurately describe the sources, extent, and severity, of contamination of Silver Bow Creek and the Upper Clark Fork River; and

- Development of data necessary to evaluate, select, and implement remedial actions.

This section generally identifies the data necessary to reach these two goals. This section has been divided into three subsections for organizational purposes.

4.1 SOURCE CONTROL

Pollution source control techniques identified in Sections 2.0 and 3.0 will require a comprehensive baseline data base to either confirm or suggest alternatives to individual technical methods. As these data are collected and analyzed, an effective remedial action plan should evolve either from the previously described methods, or from new technologies identified during the data collection process.

The general data needs described herein are based on information necessary to accurately evaluate the feasibility of the various

control technologies, in addition to filling voids in the existing data base. It is likely that these data needs will change to some extent as a study progresses owing to ongoing evaluations of the generated data.

4.1.1 Ground Water Quantity and Quality

More information is necessary to adequately characterize the quantity and quality of ground water discharge to Silver Bow Creek, Metro Storm Drain, Clark Fork River, and their tributaries. Specific ground water information is lacking for areas from the Metro Storm Drain to Rocker and for areas near Ramsay and Miles Crossing.

The type of information that will be necessary includes such things as: water surface elevation, ground water gradient, and water quality; hydrogeologic characteristics; knowledge of the interaction between ground water and surface water; and knowledge of the interaction between tailings, ground water, and surface water.

There are two primary ground water-bearing geologic units underlying the upper Silver Bow Creek watershed: alluvium and igneous bedrock. The alluvium has varying permeabilities and degrees of interactions with adjacent bedrock, and the bedrock itself has both oxide and sulfide zones. Therefore, natural variations in ground water quality must be better defined, as well as the spatial variations in degraded ground water quality due to human actions. The effects of complex geologic structures must also be evaluated.

These types of data will probably be obtained through existing domestic and stock wells in the area and/or by means of an installed observation well network. From these sources, an understanding of the area's hydrogeology and geohydrology can be attained, and specific appropriate remedial technologies can be formulated.

4.1.2 Surface Water Quality and Quantity

Although much surface water data has been collected from Silver Bow Creek and the Clark Fork River, no detailed, comprehensive sampling program has been initiated in the entire area to concurrently correlate surface water data with ground water and tailings information. As all proximal hydrologic systems are interrelated to some degree, so too is the pollution identified within these systems. It is therefore suggested that synchronous sampling be completed to document the interrelationships between physical systems.

Types of information desirable for surface water data include continuous and episodic records of quality and flow obtained concurrently from a well-designed network of gaging and sampling stations throughout the drainage. As well, an evaluation of surface water-ground water interrelationships should be made to identify losing and gaining reaches of the streams. Metals loading to Silver Bow Creek and the Clark Fork River should be quantified to document those reaches of the streams most influenced by inflows. It would be useful to calculate a mass balance of metals for the Silver Bow Creek/Upper Clark Fork River system.

Stream channel equilibrium analyses should be completed for all stream reaches believed to be affected by tailings erosion and deposition. This will necessarily include all reaches where riprapping or other channel modification has or may occur. Such analyses should also be coordinated with appropriate portions of the Tailings and Other Wastes investigations (see Section 5.1.3 following). If the data is available, a flood frequency analysis may be useful.

4.1.3 Tailings and Other Wastes

Additional data will also be necessary to identify and characterize the extensive tailings deposits in and adjacent to Silver Bow Creek and the Clark Fork River. An accurate appraisal of tailings volume should be made. Such information can be acquired through detailed field mapping complemented with depth boring data.

Data needs in this regard need to be acquired for two distinct purposes: to examine tailings and other waste deposits as the sediment being eroded and deposited by surface streams; and to examine the deposits' hydrochemical influence on shallow ground water quality.

Detailed soil characterization will be needed on a number of tailings and sediment deposits in the Silver Bow Creek and Upper Clark Fork area. Samples should be analyzed for a wide spectrum of chemical

and physical parameters to help identify the kinds of chemical reactions, acid production, soil pH changes, and trace element loading which occur in the tailings deposits. The measurements will be useful for reclamation planning.

The aspect of tailings and associated waste deposits as sediment also requires characterization. Specifically, tailings particle size distributions should be determined for a variety of affected stream reaches, and this characteristic should be compared to quantifiable stream energies and erosive power. Water quality data should also be closely examined so that available suspended sediment concentrations can be correlated with synchronous streamflow measurements. If adequate data are unavailable, provisions should be made so they are collected. Subsequently, analyses of construoted flow duration-sediment rating curves may be examined for stations along Silver Bow Creek such that field observations can be correlated with interpreted water quality data and aggrading and degrading stream reaches can be identified.

4.1.4 Point Source Discharges

Because AMC suspended Butte operations in June (1983), previous studies regarding the influence of point source discharges on Silver Bow Creek should be reassessed. Prior to the suspension of Butte operations, AMC's point source discharges contributed a significant amount of flow to Silver Bow Creek.

To determine the influence of the Metro Storm Drain on Silver Bow Creek, seasonal flow data will have to be reestablished. Seasonal composite water quality samples should be collected and analyzed for various heavy metals and other parameters of interest. From this information seasonal loadings can be computed. Runoff events should be measured and sampled.

A water quality sampling and streamflow monitoring station is needed upstream of the Butte Sewage Treatment Plant. This information, along with sewage treatment plant self-monitoring data, can be used to determine the influence of the sewage treatment plant on Silver Bow Creek.

4.2 CONTAMINATION TREATMENT

Data needs for identifying contamination treatment can be conceptually divided into data necessary for addressing irrigation-related problems and data necessary for addresesing water treatment-related problems.

4.2.1 Irrigation and Agriculture

Data needed to evaluate the various treatment alternatives includes an irrigation inventory; crop, forage, and livestock monitoring; detailed soil analyses; and characterization of water quality and quantity.

The irrigation inventory should include a summary of the acreage of irrigated land situated along Silver Bow Creek and the Upper Clark Fork River to a point downstream of Deer Lodge. On all irrigated lands the method and frequency of irrigation should be identified. In addition, the number of years that each area has been irrigated should also be estimated. Primary sources of water for major irrigation areas should also be detailed. In addition, the quality of major sources of water including Silver Bow Creek, Clark Fork River, tributaries to the Upper Clark Fork system, and shallow ground water should be identified as a function of time-of-year.

In the crop monitoring program primary crops and forages grown under irrigation should be identified. Furthermore, the information of aerial contributions to heavy metals burdens should be assessed via sampling of adjacent rangeland - uncultivated soil sites. Tissue samples of primary crops and forages at appropriate growth stages should be collected and analyzed for potential trace element contamination. Results from tissue analysis should be used to identify potential phytotoxicity or livestock trace element hazards. Where such hazards to livestock are known or suspected, tissue sampling and analysis should occur. Such tissues should include hair, whole blood or plasma, urine and milk, as appropriate.

Soil chemical and physical parameters from irrigated soils should be characterized by depth-integrated sampling to identify the extent of contamination occurring from irrigated water and to separate it from stack deposition. Samples should be collected

from the plow layer, or zero to six inches, and from additional soil horizons to a depth of four feet. Chemical and physical parameters to be characterized should include: pH; electrical conductivity; organic matter content; saturation extractable cations; sulfate and nitrate; ammonium acetate extractable calcium, magnesium, sodium, and potassium; as well as soil cation exchange capacity in unbuffered sodium chloride. The trace elements iron, manganese, zinc, copper, nickel, cadmium, and lead should be measured in either ammonium acetate extraction buffered at pH 4.2 or DTPA buffered at pH 7.5, as appropriate. Plant-extractable levels of arsenic, selenium, and molybdenum should also be measured. Total sulfur, as well as pyritic sulfur, should be measured on surface horizons. Finally, an SMP lime buffer, as well as an acid-base balance lime requirement test, should also be performed on surface samples. Soil bulk density, calcium carbonate content, and mechanical analyses, should be performed.

The above trace elements will be measured also in those tissues acquired from the livestock sampled within the study area.

Finally, ground water depth and flow direction should be identified in all major irrigated areas.

Prior to full implementation of remedial measures identified following the data gathering outlined here (and detailed in the Silver Bow Creek Remedial Investigation Work Plan) it is recommended that

test plots of proposed remedial actions be performed to measure the true performance of the remedial measures.

4.2.2 Water Treatment

Data required to evaluate the current water treatment facility, the Warm Springs Ponds, include:

- Geotechnical Data;
- Water Quality and Quantity Data; and
- Biological Data.

4.2.2.1 Geotechnical Data

Geotechnical data required for the Warm Springs Ponds should be oriented to answering three major questions:

1. What is the capacity of the ponds for additional sediment?
2. What are the factors that contributed to the pond structure's postulated inability to withstand high flow events? and
3. What are the available remedial actions available to correct the pond structure's postulated instability?

Data required for answering these questions include:

- Depth contours and calculations of available volume;
- Projected sediment loads;
- Projected high flow event data;
- Structural integrity of pond structures;
- Geotechnical characteristics of pond structure materials; and
- Geotechnical characteristics of material available for use in correcting postulated inadequacies of pond structures.

4.2.2.2 Water Quality and Quantity Data

Water quality and quantity data required for an evaluation of the Warm Springs Ponds should be designed to answer the following questions:

1. What is the current rate of sediment loading into the ponds?
2. What is the potential rate of sediment loading, assuming that source control activities are successful to a realistic degree?
3. What is the existing rate of seepage of ponded water into the ground water system and how much of this seepage ends up in the Upper Clark Fork River?

4. What is the water quality of the seepage and is it degrading local ground water systems and the Upper Clark Fork River? and
5. What are the mechanisms of metal removal and what are the equilibria conditions throughout the operating year of the pond?
6. How much water bypasses the ponds and is not treated, and why?

The data necessary to answer some of these questions may already exist to some degree. However, additional data in several key areas still needs to be collected. This data includes the following:

- The remedial investigation program should collect water quality data on all ponds throughout a full operating year including high flow events, winter icing, and other seasonal events. This data should include all standard water quality measurements, nutrients loads, coliform load, plus measurements of trace elements. Additionally, data on organic contaminants reaching the ponds should be collected. Data collection sites should include inflow sites, outflow sites, and representative stillwater sites. The final number of sites chosen should be based on statistical predictions for reaching specific goals of precision, accuracy, and confidence. Timing of data collection should be coordinated with

data collection on Silver Bow Creek so that data sets are more useful in evaluating the complete Silver Bow Creek - Warm Springs Ponds - Upper Clark Fork River System. The critical January-April period should be given special attention.

The data collected from this program should be used to characterize current operation of the ponds and to calculate the following:

- Yearly contaminant load coming into the ponds;
- Yearly contaminant load being deposited into the ponds from current treatment methodologies;
- Yearly contaminant load passing into the Upper Clark Fork River;
- Yearly contaminant loads bypassing the Warm Springs Ponds.

Additionally, the data may show certain seasonal patterns that could be addresed in any plans for modifying current operation of the ponds. The data should also be useful in predicting loads to the ponds assuming source control actions are successful to some degree.

The remedial investigation should address the potential problems to ground water and surface water from seepage from the ponds. Existing data is not sufficient to accurately characterize the volume, quality, or ultimate fate of seepage from the ponds. Additional wells need to be drilled to supplement existing wells for the

collection of piezometric and water quality data. Placement of the wells should be determined from a review of existing well data.

4.2.2.3 Biological Data

In order to help characterize the current operation of the ponds and to help identify those factors that contribute to the metal removal capacity of the ponds on a seasonal basis, it is recommended that certain biological studies be performed as part of the remedial investigation. The justification for performing these studies is that the heavy metal removal and/or transport occurring in the Warm Springs Ponds is probably due to a combination of physical, chemical, and biological action. The water quality studies previously identified should give answers regarding the physical and chemical factors controlling trace element movement. However, the contribution of biological processes is currently unknown and may or may not affect trace element movement. This unknown should be investigated.

Algae have been shown to have some species that are effective at trace element accumulation. To determine the contribution algae makes to metal removal or transport in the Warm Springs Ponds, the following types of data should be collected:

- Seasonal biomass estimates of algae.

- Sesonal measurements of metal concentrations by algae through analysis of algal tissue for selected trace elements.

- Seasonal measurements of algal deposition versus discharge (algae that concentrate metals and are discharged do not effect removal).

- Seasonal identification of major algal species for comparison with literature data for species ability to accumulate metals.

- Calculation of total metal removal or transport contribution by algae using biomass estimates and measurements of trace element concentrations in algal tissue.

4.3 ADDITIONAL DATA NEEDS

Additional data needs can be divided into data needed for evaluation of source control or treatment methodologies and data needed for describing the extent and severity of contamination.

4.3.1 Source Control and Treatment

One of the proposed treatment techniques is the construction and operation of an upstream reservoir on Blacktail Creek and another reservoir on Basin Creek to control the flow of relatively uncontaminated water into Silver Bow Creek. In order to consider this

alternative, data would need to be gathered to help determine possible locations and designs for such a reservoir, as well as to quantify runoff available for such storage. Data for this evaluation would need to address the following:

- Drainage Basin Runoff Characteristics;
- Geology;
- Geotechnical;
- Topography;
- Land Planning;
- Land Ownership;
- Liability and Operational Responsibility; and
- Operational Needs.

Several of the source control and treatment methodologies would require the removal and disposal of large volumes of tailings, wastes, and sediments. In order to evaluate these technologies, additional data on potential storage sites may be necessary. This data would include information on:

- Geology
- Geotechnical;
- Topography;
- Land Planning;
- Land Ownership;
- Liability and Operational Responsibility; and
- Operational Needs.

4.3.2 Describing the Extent and Severity of Contamination

Additional biological data is needed to adequately describe the extent and severity of contamination of Silver Bow Creek. This biological data is needed in several specific areas. These are:

- Aquatic communities of Silver Bow Creek;
- Potential waterfowl contamination from Silver Bow Creek, the Warm Springs Ponds, and the Upper Clark Fork River;
- Effects to natural vegetation in the Silver Bow Creek and Upper Clark Fork River floodplains from contaminated water; and
- Effects to the fisheries of the Upper Clark Fork River from current operating conditions of the Warm Springs Ponds.

4.3.2.1 Aquatic Communities

Several recent studies of the aquatic communities in Silver Bow Creek have found that the creek is continuing to recover following implementation of water treatment by AMC in the early 1970's, (Chadwick and Associates 1982; Harner-White Ecological Consultants, Inc. 1983). However, additional studies should be implemented to confirm this trend conclusion and to provide an adequate data base for future evaluations of the success of source control and treatment

actions. These studies should duplicate, as much as feasible, the studies by Chadwick and Associates (1982) and Harner-White Ecological Consultants, Inc. (1983) the methods employed should include benthic macroinvertebrate surveys and algal surveys. Site locations for sampling should include those sites previously sampled and some additional sites in the Upper Clark Fork River between Warm Springs and Deer Lodge. Sampling should occur to document seasonal phenomena.

4.3.2.2 Waterfowl Contamination

Due to their position in the food chain, waterfowl are in a position to accumulate excessive amounts of contaminants in their body tissue. These excessive amounts of contamination may not only be detrimental to the waterfowl resources of the study area, but may also be detrimental to human consumers of affected waterfowl.

Because waterfowl hunting is a popular sport on the waterways of this system and, in order to better document and evaluate this potential human health threat, it is recommended that remedial investigations address this issue. Data necessary to evaluate this problem include:

- Number, species, composition, and habitat use of waterfowl using contaminated water areas.

- Levels of suspected contaminants in resident and migratory waterfowl on a species- and tissue-specific basis.

- Number of waterfowl harvested and consumed from contaminated waterways.

Given this data, it would be possible to evaluate the health threat to human comsumers of waterfowl harvested from Silver Bow Creek, the Upper Clark Fork River, and the Warm Springs Ponds.

4.3.2.3 Effects to Natural Vegetation

In order to document effects to local vegetation from contamination it is recommended that the vegetation of the Silver Bow Creek - Upper Clark Fork River (including the Warm Springs Ponds) floodplain be mapped. This mapping would serve the following useful purposes:

- By comparing the vegetation map to a map of tailings and other waste deposits, an estimate of the number of acres lost to contamination effects could be made.

- By evaluating those vegetation map units that appear to be surviving in the face of contamination, potential species for revegetation and reclamation may be identified.

Methods used to map the floodplain vegetation would include:

- Identification of mapping units;
- Characterization of mapping units;

- Mapping the units; and
- Field verification of mapping.

4.3.2.4 Effects to Fisheries of the Upper Clark Fork River

Much concern has been expressed over the effects contamination within the Silver Bow Creek - Upper Clark Fork River system has had on the fisheries of the Upper Clark Fork River; specifically, the effects on the brown trout fishery. In order to better document the actual effects the existing levels of contaminants have on the brown trout of the Upper Clark Fork River, it is recommended that a bioassay study be performed. This study should have the specific goal of answering the following question:

- Does contamination from Silver Bow Creek and the Warm Springs Ponds affect the production of brown trout or prevent the establishment of a rainbow trout fishery in the Upper Clark Fork River?

The study plan should describe:

- Sampling sites;
- Dilution factors;
- Fish acquisition;
- Fish age;
- Factors controlling current production;

- Appropriate bioassay tests;
- Appropriate accompanying water quality tests; and
- Fish tissue trace element accumulation.

5.0 APPENDIX

5.0 APPENDIX

5.1 REFERENCES

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5.2 PRINCIPAL AUTHORS

Name	Affiliation
Ed Casne	Stiller and Associates
Jay Cornish	MultiTech
Myles Grotbo	Stiller and Associates
Rod James	Sawyer-Waring and Associates
Kirk Miller	Stiller and Associates
Dr. William Schaffer	Soil Resource Consulting
David Stiller	Stiller and Associates
Robert Trout	MultiTech